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Preliminary Scientific Assessment of the July 2004 SEPTR Test Deployment

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Initial results are presented from a July through September 2004 test deployment done with a modified, preliminary version of SEPTR (circa 2003). The SEPTR performed well overall, returning twice-daily vertical profiles of temperature and salinity, in addition to nearly continuous profiles of velocity. However, a number of problems requiring attention were identified. These include an intermittent failure of the battery charger, which caused the profiler to stay near the surface for extended periods of time, periods in which no data were transmitted, premature shut-down of the ADCP, problems with the wave-measurement system, and sensor response differences which led to unrealistic salinity spikes. It is hoped that results from this test deployment will help identify problems and improve performance during further development of SEPTR through a Cooperative Agreement between the Naval Research Laboratory and the NATO Undersea Research Centre.

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Introduction

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Data

The SEPTR used for this test deployment profiled at 12-hr intervals between July 1 and September 28, 2004, completing 176 profiles over the course of the deployment. Data from down-going profiles were stored and relayed (along with accumulated ADCP data) to a satellite once per profile. To measure surface wave characteristics the profiler stopped several meters below the surface on each upcast, taking pressure readings at approximately 9 Hz over a 28-second period before continuing to the surface.

For this deployment each recorded conductivity, temperature, and pressure value during the downcast was the result of averaging 35 samples. These 35 samples were acquired as quickly as possible, although the precise averaging time is difficult to specify because of unknown `dead times' between acquitions. The time to acquire 35 samples is roughly 50 ms. Sample storage is triggered by the pressure increment, with acquisition of T, S data done at 1 dbar intervals. The profiler moved at about 30 cm/s, and so the effective sampling rate during a downcast is close to 0.3 Hz. The `raw' sampling rate (before averaging) is however much higher, between 3 Hz and 20 Hz (A. Carta, pers. comm.). It is not possible to store data at a rate faster than 6 Hz because of dead times between the acquisitions.

Wave data are derived from pressure measurements made by an IDRONAUT pressure gauge during profiler upcasts. The wave sampling interval was 0.110 sec (a 9 Hz sampling rate), with a total of 256 samples collected during each 28.07 sec sampling burst. Samples were taken every 12 hours at approximately 09:36 and 21:36. Each wave data file contains wave spectral density, surface elevation, wave variance and significant wave height, and profiler depth.

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A 600 kHz ADCP was incorporated into the SEPTR; the ADCP was programmed to ping at 1 Hz, and 45 pings were averaged per hourly ensemble. ADCP data were recorded in discrete depth bins, with the bottom of the first depth bin 2.5 m above the bottom and a bin size of 1.5 m. There were at total of 24 bins.

Results

Profiles of temperature, conductivity, salinity, and σ_t (i.e., density-1000 kg/m^3) for profiles 30-40 are shown in figure 1. These show fairly clean profiles of temperature, which resolve the structure of the water column rather well. Conductivity profiles also appear to be clean and free of spikes. By contrast, salinity values computed from C and T appear quite noisy, exhibiting large spikes, especially near the thermocline. The amplitude of these spikes is often larger than 1 PSU, occasionally approaching 2 PSU - large enough to produce apparent inversions in computed density profiles (figure 1). Given the relatively slow (30 cm/s) profiling speed of the CTD these inversions are physically unrealizable (implying inversions persist for O(1 sec)), and we conclude that they are sampling artefacts. The large amplitude of the computed overturns also indicates they are not real. In addition, vertical velocity data (not shown) show no corresponding large spikes, which would be expected if these overturns were real. Salinity spikes like these are a common problem with raw CTD data, especially in high-gradient regions where effective lag times between T and C sampling (due to both physical separation between sensors and differing sensor response times) can lead to large salinity spikes. Noise due to spiking can be minimized by lagging measured temperature values relative to conductivity by an appropriate amount, and initial results from our post-processing of the SEPTR data suggest this is the case here. Further analysis should yield optimal effective lags which can be incorporated into the SEPTR data processing software.

Plots comparing SEPTR profile data with raw data from a Seacat profiling CTD are shown in figure 2. The top panels show the first SEPTR profile together with a Seacat profile done following deployment on July 1st (the Seacat profile was done within minutes of the SEPTR profile). The bottom panels show data from concurrent Seacat and SEPTR profiles on August 8th. Good agreement is apparent between the two instruments, especially for temperature, with the largest differences occurring in regions of strong vertical gradient (probably a result of up/down motions associated with internal waves). Salinity measurements from the two instruments also agree reasonably well, although there is a fair amount of spikiness in the salinity data, because sensor time-response mis-match corrections were not applied to these data. Still, the data agree rather well in the mean, and there is little indication of conductivity drift over five-week period shown here.

Contour plots of temperature, salinity, and σ_t are shown in figure 3. The temperature plot shows strong vertical gradients and large temporal variability. Temperatures range from 16°C near the bottom to 26°C at the surface. Salinity and σ_t plots are significantly noisier, showing a high degree of spiking near the mid-depth thermocline. Profiles were done twice per day, and occasional aborted profiles during which the profiler remained close to the surface between profiles are indicated by gaps in the contour plot. This happened more than 10 times during the the deployment, so was by no means uncommon. This resulted from a battery charger problem identified after recovery (A. Carta, pers. Comm.). It is extremely important that this problem be corrected prior to operational deployment of SEPTR, since remaining exposed at the surface between profiles puts the profiler at great risk from passing ships.

In addition the aborted profiles discussed above, there were two periods in which the SEPTR transmitted no data to shore (10-13 Sept and 21-24 Sept), and it is unclear at this point what might have caused these transmission failures. However, the 19 missing profiles were stored in SEPTR and were successfully retrieved after recovery.

SEPTR velocity data are shown in figure 4. The contour plot shows velocity magnitude (m/s) for the period from July 2 – September 2. Most values are near zero, but there are a number of `pulses' during which speeds increase to 20 cm/s or more. Blank areas at the top of the plot are the result of exclusion of bad data in the surface interference zone by the ADCP processing software. As typical with bottom deployed ADCP data, velocities near the surface (range > 28 for this deployment) are contaminated by direct surface echos and should be discarded. The ADCP stopped sampling early, five days before the final CTD profile; this was due to a software problem that is being corrected (A. Carta, pers. Comm.).

Two wave spectra are shown in figure 5a. The spectrum truncated at 0.213 Hz comes from wave measurements made at a depth of about 17.8m. Pressure fluctuations are smoothed at this depth (figure 5b) due to the greater attenuation with depth of shorter waves. The spectrum showing energy density extending above 0.2 Hz comes from more detailed surface wave data taken very close to the surface (1.3m depth). Calculated wave height, spectral density versus time, and wave-sampling depth for the entire deployment period are shown in figure 6. Most wave data taken during this deployment come from deeper depths (between 17 and 19m), and only a few come from measurements made near the surface (see figure 6c).

It is unclear why the profiler made wave measurements at two different depths. The degree to which wave measurements are contaminated by up/down motion of the profiler during the wave sampling period is unknown and should be investigated; this will require an independent measure of surface wave characteristics in a future deployment. The 28-sec wave sampling period appears to be too short to construct a meaningful and representative surface wave spectrum. A sampling period of at least 5 min is needed for the spectral calculation. The 9 Hz sample rate provides spectral information at frequencies up to 4.5 Hz. However, the pressure signals of these higher-frequency waves are probably attenuated significantly and cannot be practically measured. Therefore, a sample rate of about 1 Hz should be sufficient for these wave measurements.

Conclusions

The SEPTR represents a substantial improvement over conventional Barny technology, giving near real-time velocity, temperature, and salinity data. Initial results from this test are encouraging, however there are a number of technical difficulties outlined here which need to be addressed before the SEPTR can be used routinely in the field.

The sampling parameters chosen for this deployment were not optimal for oceanographic purposes. At the 30 cm/s speed of the profiler it should be possible to sample at 10 cm intervals in future tests; this would improve the quality of SEPTR CTD data considerably. Similarly, with a 600 kHz ADCP vertical resolution of 50 cm should be possible, and to decrease measurement error an increased ensemble interval of ~15 min and a burst duration of 2-3 minutes is recommended. These changes can be evaluated against any increased risk to the SEPTR resulting from extended data transmission times.

In summary, our recommendations are:

- Correct the battery charging problem that led to numerous aborted profiles and would be a serious risk to the safety of the instrument in a real deployment.

- Diagnose and address data gaps spanning several days during which SEPTR transmitted no data.

- Increase vertical resolution of CTD records from 1 dbar to approximately 0.1 dbar (10 cm) to better resolve the small-scale structure of the water column.

- Incorporate an appropriate lag in conductivity measurement into data logging software in order to minimize salinity-spiking errors.

- Increase vertical resolution of ADCP data from 1.5 m to 50 cm, and increase the ensemble averaging interval to ~15 min to improve signal/noise characteristics.

- Correct the software problem which caused the ADCP to stop sampling prematurely.

- Address problems with wave-measurement system which caused the profiler to take wave samples at two different depths.

- Increase the period of wave measurement to ~5 minutes to better resolve surface wave spectra, and decrease the sample rate to 1 Hz.

- Assess the effect of wave-induced up/down motion of the profiler during wave sampling on the quality of surface wave measurements.

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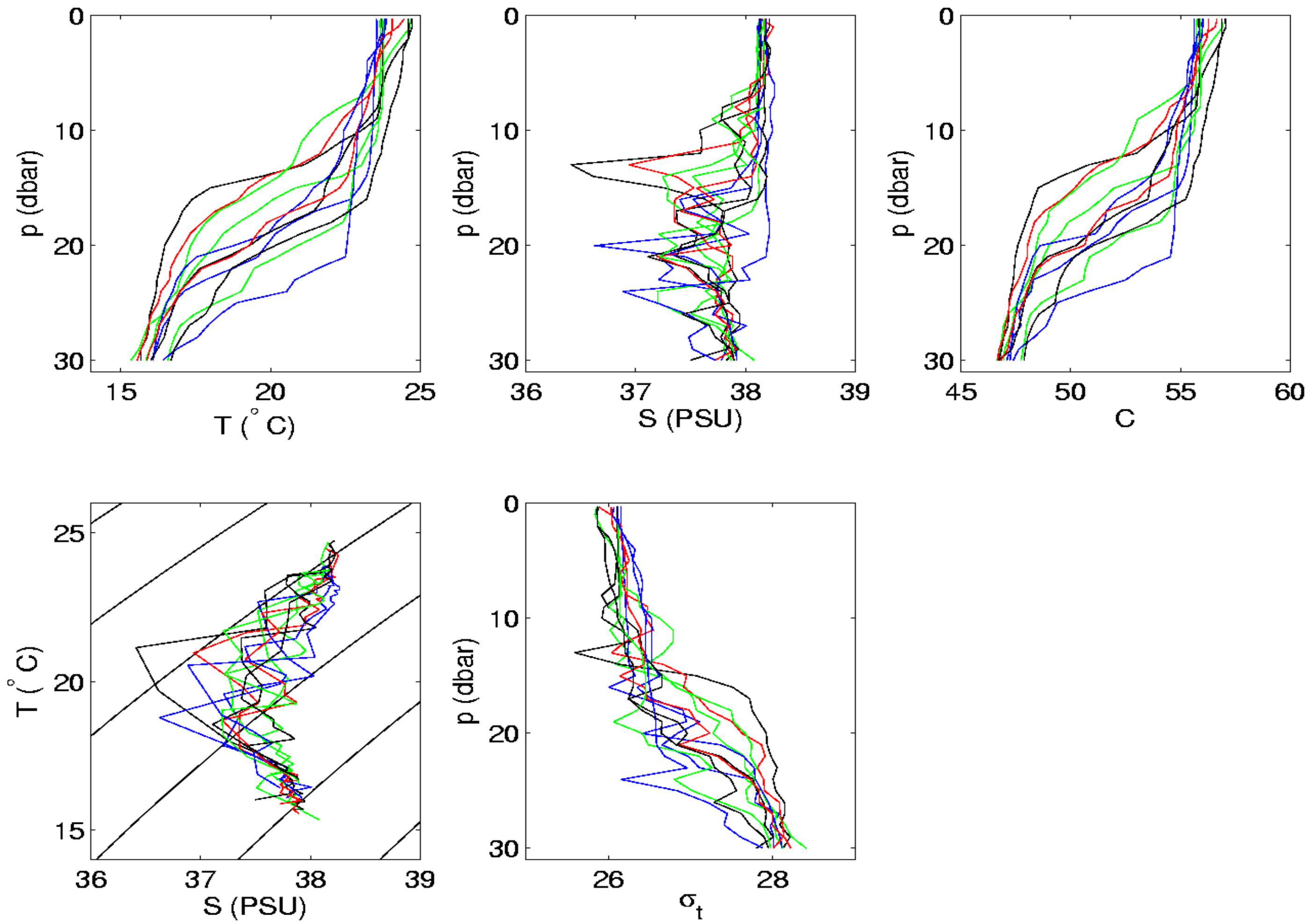

Figure 1: Temperature, salinity, conductivity, and σ_t profiles for profiles 30-40, together with a T-S plot. Salinity spikes and associated density spikes are apparent in high-gradient regions.

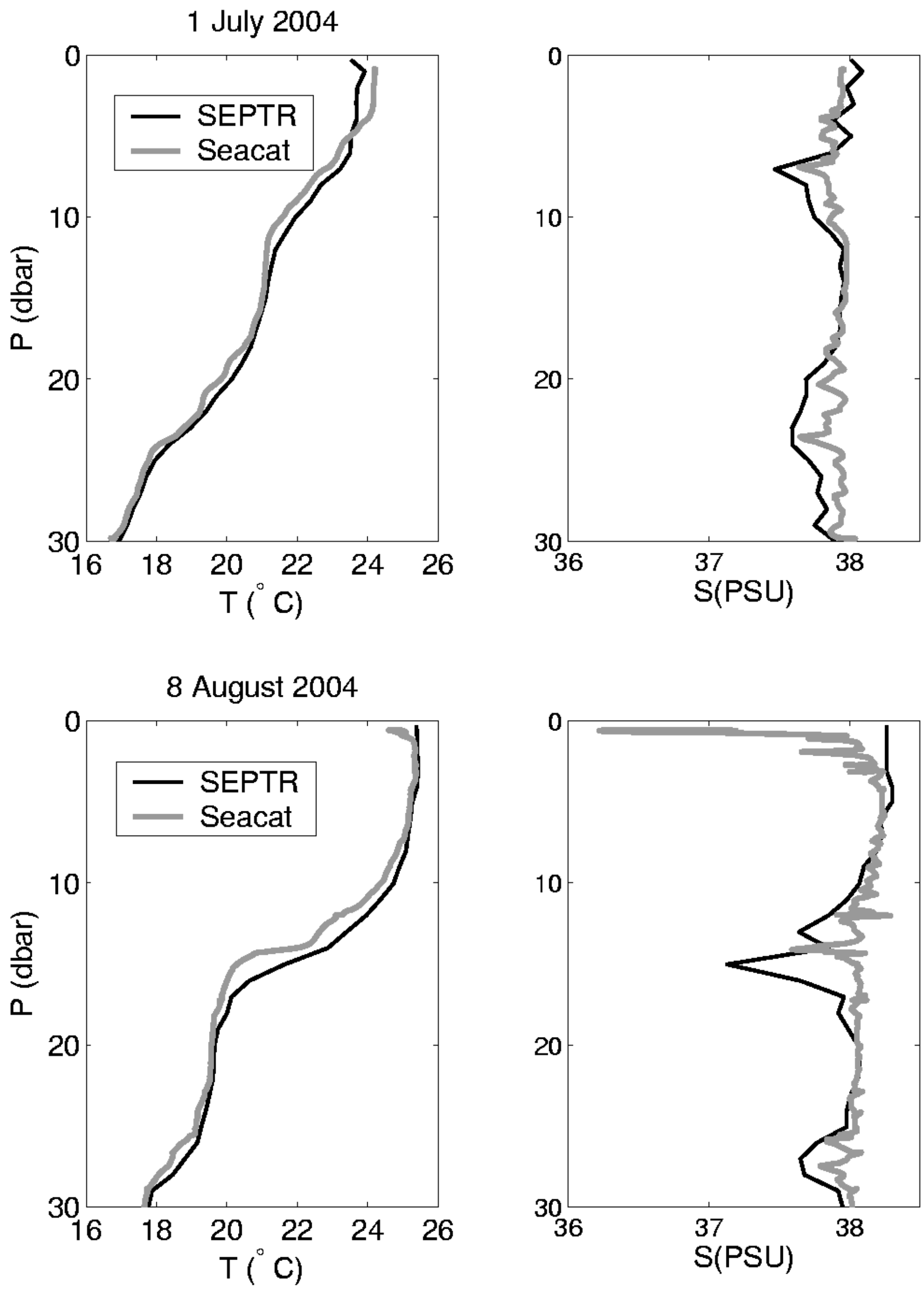

Figure 2: Comparison of SEPTR CTD profile data with raw data from a seacat profiling CTD. Temperature (left panels) and salinity (right panels) shows reasonably good agreement, for both the July comparison (top) and the August comparison (bottom).

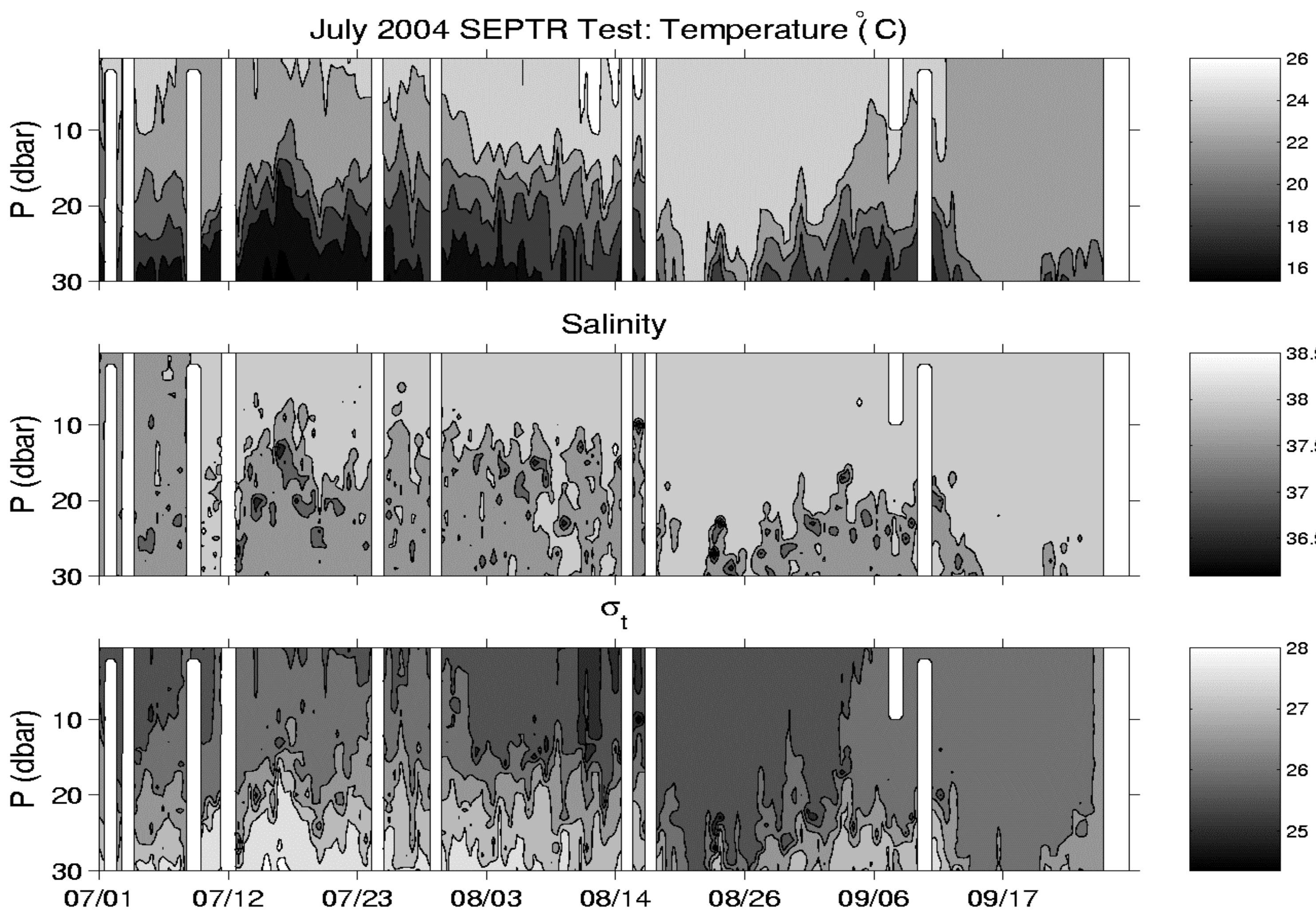

Figure 3: Time-depth contour plots of T (top), S (middle), and σ_t (bottom), providing a detailed view of the evolution of the water column over time. Gaps in the contour plot show aborted profiles, after which the profiling CTD remained near the surface.

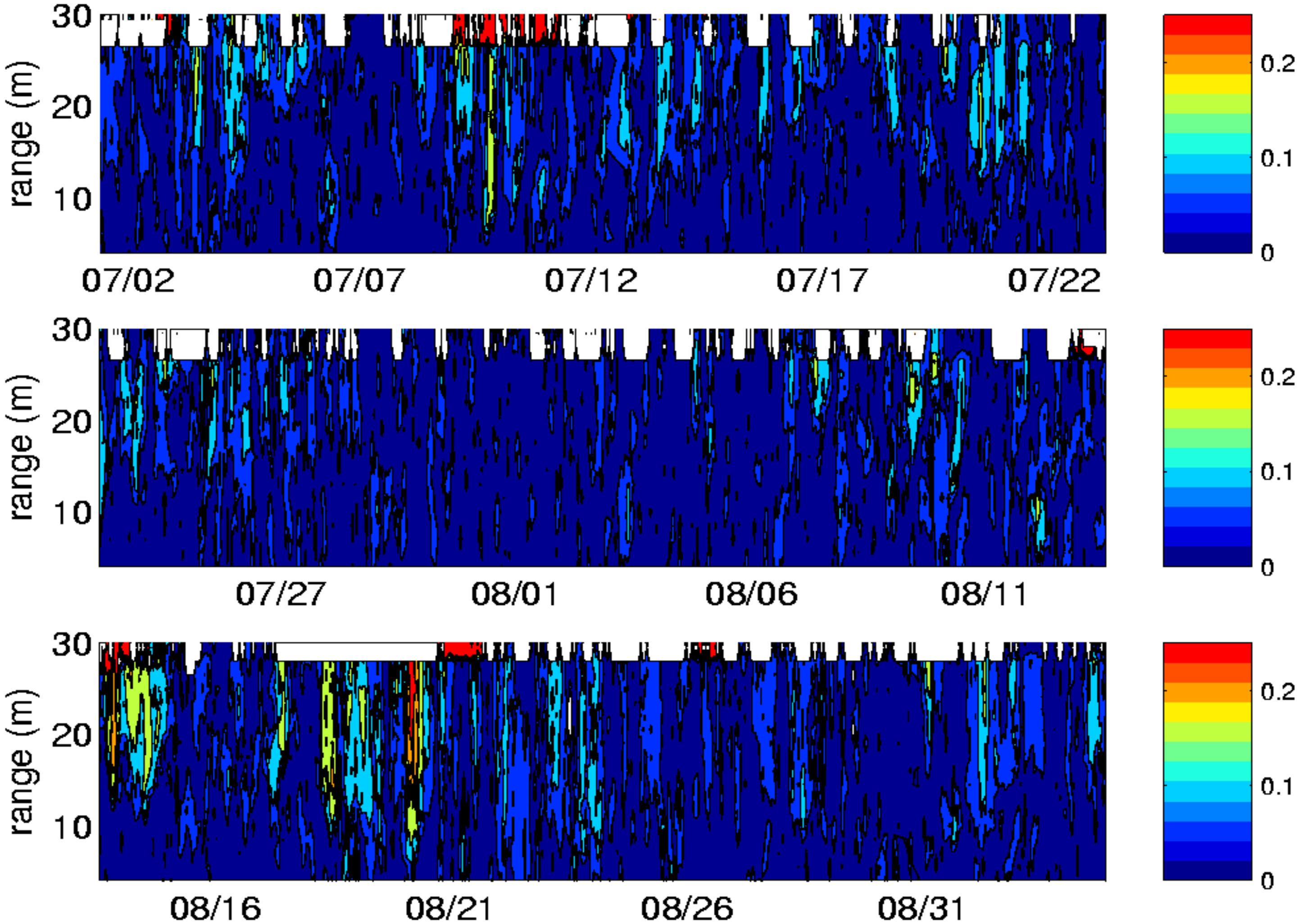

Figure 4: Depth-time contour map showing speeds (m/s) measured by the SEPTR ADCP.

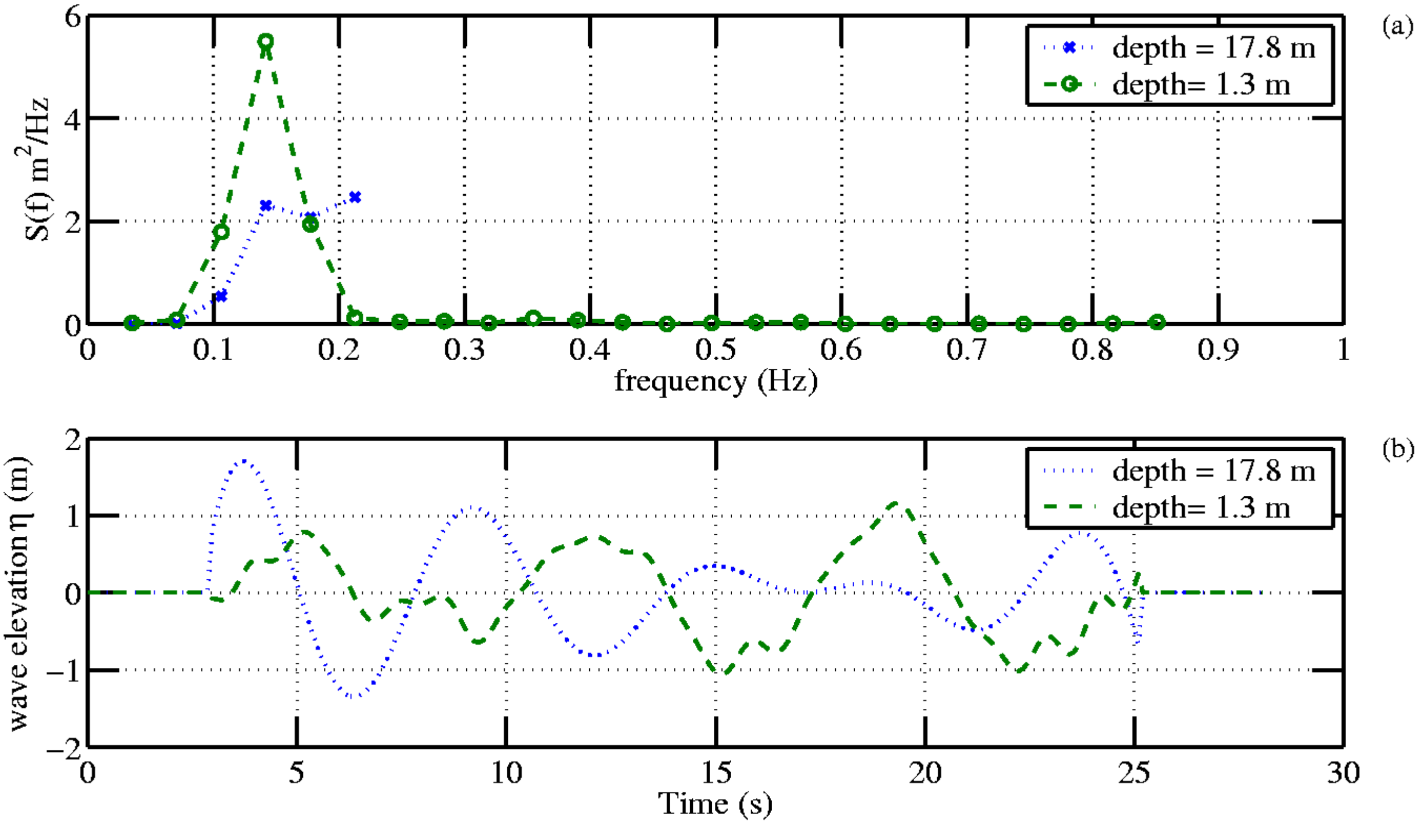

Figure 5: Examples of wave spectra and surface wave elevation measured during two wave sampling bursts (calculated from files 2004-07-09@09.35.54.txt and 2004-07-09@21.31.36.txt).

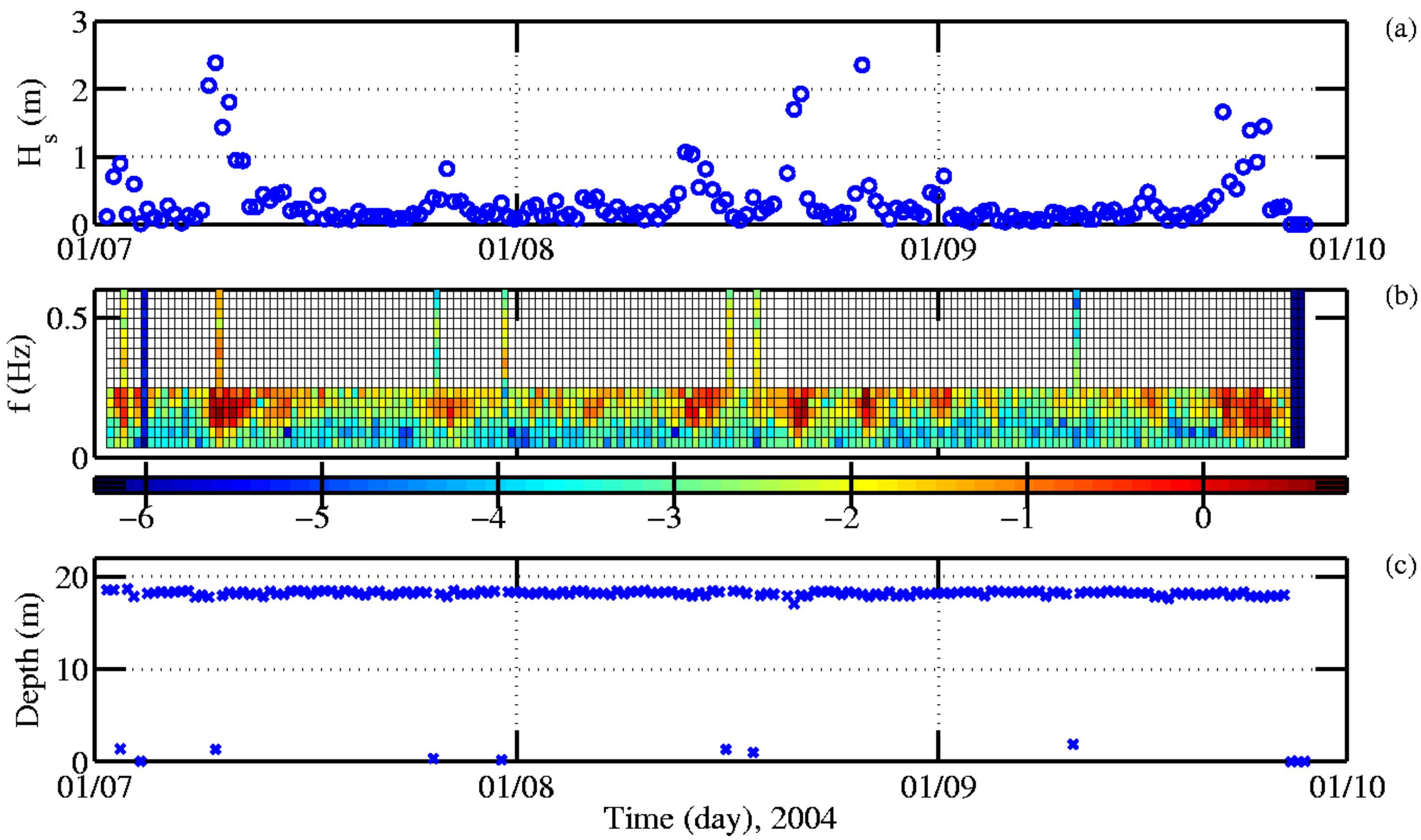

Figure 6: Significant wave height (top), spectral density as a function of time (middle), and profiler depth when the wave measurement was made (bottom). Power spectral densities are plotted using a logarithmic color scale.